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A direct evaluation of the Λ_c^+ absolute branching ratios: a new approach

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Abstract

A novel method for a direct measurement of the exclusive Λ_c^+ branching ratios is here described. The approach is based on the peculiar topology of the quasi-elastic charm neutrino-induced events on nucleons. The intrinsic potentiality of the method is thoroughly discussed using a *perfect detector*. As an application, the statistical accuracy reachable with existing data sample has been estimated. From a theoretical point of view, such measurement provides a better understanding of the baryonic b-decays.

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1 Introduction

There exists no direct measurement of $BR(\Lambda_c^+ \to pK^-\pi^+)$. However, using different assumptions and experimental data, two indirect determinations of the above branching ratio have been given [1, 2]. These two values are quite different, and thus it is likely that one of the procedures is incorrect.
Note that, since the channel $\Lambda_c^+ \to pK^-\pi^+$ is used for normalisation, a change in its branching ratio will affect most of the Λ_c^+ exclusive decay widths.

Here we propose a method, based on neutrino quasi-elastic charm production process, to directly measure the Λ_c^+ branching ratios. This measurement, solving the above puzzle, will provide new insight on the underlying hadronic physics.

This letter has the following structure: in Section 2 we discuss the two different determinations of $BR(\Lambda_c^+ \to pK^-\pi^+)$ and the physics impact of a direct measurement. In Section 3, the charm production in neutrino scattering is analysed by studying topology, kinematics and cross-sections of quasi-elastic processes and deep inelastic reactions, which are the main source of background. The evaluation of the accuracy achievable for these Λ_c^+-exclusive decay widths in neutrino scattering is performed in Section 4. In the last section, we give our conclusions.

2 Model dependent extraction of $BR(\Lambda_c^+ \to pK^-\pi^+)$

As stated above, two different methods to extract $BR(\Lambda_c^+ \to pK^-\pi^+)$ from the experimental data have been proposed in literature [1, 2].
Method $\mathcal{A}$
The ARGUS [3] and CLEO [4] experiments have measured the quantity $BR(\bar{B} \to \Lambda_c^+ X)\times BR(\Lambda_c^+ \to pK^-\pi^+)$. Moreover, under the assumptions that $\Gamma(\bar{B} \to \text{baryon } X)$ is dominated by $\bar{B} \to \Lambda_c^+ X$, CLEO [4] and ARGUS [5] have been able to determine the branching ratio $BR(\bar{B} \to \Lambda_c^+ X)$. Thus, combining these above measurements one obtains [1]

$$BR(\Lambda_c^+ \to pK^-\pi^+) = (4.14\pm0.91)\% \quad . \tag{1}$$

It is worth pointing out, as emphasised in [2], that in order to derive $BR(\bar{B} \to \Lambda_c^+ X)$

i) Ξ_c and Ω_c production in $\bar{B}$-decays,

ii) $\bar{B} \to D^* \bar{N} N X$ like decay channels

have been neglected.
Method $\mathcal{B}$
A different determination of $BR(\Lambda_c^+ \to pK^-\pi^+)$ is based on the independent measurements of [6, 7]

$$\sigma(e^+e^- \to \Lambda_c^+ X)\times BR(\Lambda_c^+ \to pK^-\pi^+)\,, \tag{2}$$

and [8, 9]

$$\sigma(e^+e^- \to \Lambda_c^+ X)\times BR(\Lambda_c^+ \to \Lambda l^+ \nu_l)\,. \tag{3}$$

Averaging over the results of the two experiments one obtains [1]

$$\begin{aligned} R &\equiv \frac{BR(\Lambda_c^+ \to pK^-\pi^+)}{BR(\Lambda_c^+ \to \Lambda l^+ \nu_l)} = \frac{\sigma(e^+e^- \to \Lambda_c^+ X)\times BR(\Lambda_c^+ \to pK^-\pi^+)}{\sigma(e^+e^- \to \Lambda_c^+ X)\times BR(\Lambda_c^+ \to \Lambda l^+ \nu_l)} \\ &= 2.40\pm 0.43\,. \end{aligned} \tag{4}$$

Then the branching ratio for $\Lambda_c^+ \to pK^-\pi^+$ can be obtained from the following relation

$$BR(\Lambda_c^+ \to pK^-\pi^+) = \frac{R\cdot f\cdot F}{1+\mid V_{cd}/V_{cs}\mid^2}\,\Gamma(D^0 \to X l^+ \nu_l)\,\tau(\Lambda_c^+)\,, \tag{5}$$

where

$$f \equiv \frac{BR(\Lambda_c^+ \to \Lambda l^+ \nu_l)}{BR(\Lambda_c^+ \to X_s l^+ \nu_l)}\,, \tag{6}$$

$$F \equiv \frac{\Gamma(\Lambda_c^+ \to X_s l^+ \nu_l)}{\Gamma(D^0 \to X_s l^+ \nu_l)}\,. \tag{7}$$

The ratio f is obviously <1 since there are non-vanishing contributions to the leading $X_s = \Lambda$ from $\Sigma^\pm\ \pi^\mp$, and $n\bar{K}^0, pK^-$, which however are phase space suppressed. The analogous fraction for the meson D has been measured by CLEO [10]

$$\frac{\Gamma(D \to (K+K^*) l^+ \nu_l)}{\Gamma(D \to X_s l^+ \nu_l)} = 0.89\pm 0.12\,. \tag{8}$$

Thus one can reasonably expect $f \simeq 0.9\pm 0.1$. In any case, experiments might measure f directly.

Theoretical estimates of F are based on Operator Product Expansion in the framework of the heavy quark effective theory [11], where the amplitudes for $\Lambda_c^+ \to X_s l^+ \nu_l$ and $D^0 \to X_s l^+ \nu_l$ are predicted to have the same leading terms, while the $\mathcal{O}(1/m_c^2)$ corrections are found to be larger for Λ_c^+. As a result $F = 1.3\pm 0.2$ [11]. Thus, if one uses for R the value of Eq.(4) and [1] for

$$1+\mid V_{cd}/V_{cs}\mid^2 = 1.05\,, \tag{9}$$

$$\Gamma(D^0 \to X l^+ \nu_l) = (0.163\pm 0.006)\times 10^{12}\ s^{-1}\,, \tag{10}$$

$$\tau(\Lambda_c^+) = (0.206\pm 0.012)\times 10^{-12}\ s\,, \tag{11}$$

we obtain from Eq.(5)

$$BR(\Lambda_c^+ \to pK^-\pi^+) = (7.7\pm 1.5\pm 2.3)\%\,. \tag{12}$$

Ref. [1] gives the weighted value of the two measurements $BR(\Lambda_c^+ \to pK^-\pi^+) = (5.0\pm 1.3)\%$, where also the theoretical uncertainty is included. However, it is also stressed that this number is rather arbitrary. Indeed Ref. [2] advocates method $\mathcal{B}$ suggesting that one should reanalyse the existing $\bar{B} \to$ baryon sample to look for $\bar{B} \to D^*\bar{N}NX$ decay channels. As a result, if this interpretation is correct, then:

$\sigma(10^{-39}\ cm^2)\backslash$ Model	F.R. [12]	S.L. [13]	A.K.K. [14, 15, 16]	A.G.Y.O. [17]	K. [18]
$\nu_\mu p \to \mu^- \Sigma_c^{++}$	0.02	0.9	0.8	0.1	0.3
$\nu_\mu p \to \mu^- \Sigma_c^{*++}$	0.06	1.6	1.0	0.06	-
$\nu_\mu n \to \mu^- \Lambda_c^{+}$	0.1	2.3	4.1	0.3	0.5
$\nu_\mu n \to \mu^- \Sigma_c^{+}$	0.01	0.5	-	0.06	0.15
$\nu_\mu n \to \mu^- \Sigma_c^{*+}$	0.03	0.8	-	0.03	-

Table 1: Predicted quasi-elastic charm production cross-section assuming a neutrino energy of 10 GeV.

i) heavy baryon tables would change;

ii) measured charm counting in b-decay would decrease;

iii) $\bar{B} \to$ baryon decay models should be reanalysed.

3 Neutrino charm production

3.1 Neutrino quasi-elastic charm processes

The simplest exclusive charm-production reaction is the quasi-elastic process where a $d-$valence quark is changed into a $c-$quark, thus transforming the target nucleon into a charmed baryon. Explicitly the quasi-elastic reactions are

$$\nu_\mu n \to \mu^- \Lambda_c^+(2285), \tag{13}$$

$$\nu_\mu p \to \mu^- \Sigma_c^{++}(2455), \tag{14}$$

$$\nu_\mu n \to \mu^- \Sigma_c^{+}(2455), \tag{15}$$

$$\nu_\mu p \to \mu^- \Sigma_c^{*++}(2520), \tag{16}$$

$$\nu_\mu n \to \mu^- \Sigma_c^{*+}(2520). \tag{17}$$

In literature there are two classes of models which try to describe the processes (13)-(17). The first class [12]-[17] is based on the $SU(4)$ flavour symmetry, but since $SU(4)$ is badly broken, the parameters (axial and vectorial mass) entering the cross-section formula cannot be reliably predicted.

A different approach [18] is based on the Bloom-Gilman [19] local duality in νN scattering modified on the basis of QCD [20, 21].

The cross-sections predicted by the different models, assuming a neutrino energy of 10 GeV, are shown in Table 1. As we can see, these predictions can even differ by one order of magnitude. From Fig. 3 in Refs. [13] and [18] we note that the total cross-section in both models is almost flat for a neutrino energy larger than 8 GeV.

Only one measurement of the neutrino quasi-elastic charm production cross-section exists. The E531 experiment [22], based on a sample of 3 events and

Reaction	$\sigma(10^{-39}\ cm^2)$	$\mathcal{R}(\%)$	Expected events
$\nu_\mu p \to \mu^- \Sigma_c^{++}$	0.14	0.14	1400
$\nu_\mu p \to \mu^- \Sigma_c^{*++}$	0.06	0.06	600
$\nu_\mu n \to \mu^- \Lambda_c^{+}$	0.3	0.3	3000
$\nu_\mu n \to \mu^- \Sigma_c^{+}$	0.07	0.07	700
$\nu_\mu n \to \mu^- \Sigma_c^{*+}$	0.03	0.03	300
All	0.6	0.6	6000

Table 2: Quasi-elastic charm production cross-section and its contribution to the total charged-current neutrino cross-section. In the last column the expected number of events, assuming a starting sample of 1 million charge-current neutrino-induced events, is shown.

using a neutrino beam with an average energy of $\sim 22\ GeV$, measured the Λ_c^+ quasi-elastic production cross-section to be:

$$\sigma(\nu_\mu n \to \mu^- \Lambda_c^+) = 0.37^{+0.37}_{-0.23} \times 10^{-39}\ cm^2$$

$$\mathcal{R} \equiv \frac{\sigma(\nu_\mu n \to \mu^- \Lambda_c^+)}{\sigma(\nu_\mu N \to \mu^- X)} = 0.3^{+0.3}_{-0.2}\%$$

Despite the large statistical error, this measurement is clearly inconsistent with the predictions of Refs. [13]-[16], while the agreement is fair for [12, 17, 18]. An average value of the cross-sections predicted by Refs. [12, 17, 18] has been used to have a rough estimate of the expected number of events, see Table 2.

3.2 Topology of the quasi-elastic events

In the quasi-elastic processes (13)-(17), besides the charmed baryon, only a muon is produced at the interaction point (primary vertex). For reaction (13) we expect the topology shown in Fig. 1a), namely, a muon track plus the Λ_c^+ immediately decaying. For reactions (14) and (16), since the produced Σ_c^{++} strongly decays into a Λ_c^+ and a π, we expect three charged particles at the primary vertex as shown in Fig. 1c). For reactions (15) and (17) we expect a number of charged particles produced at the primary vertex equal to the one of reaction (13), plus a neutral pion produced in the Σ_c^+ decay (see Fig. 1b)).

Indeed, these events are characterised by a peculiar topology: two charged tracks produced at the primary vertex, with Σ_c, if present, decaying strongly. In any case, the final charmed baryon can only be a Λ_c^+. This feature is very important and will be exploited heavily in the following.

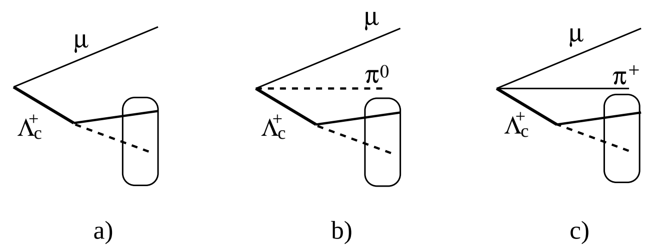

Figure 1: Topology of the quasi-elastic charm neutrino induced events in the case of the reaction a) $\nu_\mu n \to \mu^- \Lambda_c^+$, b) $\nu_\mu n \to \mu^- \Sigma_c^+ (\Sigma_c^{*+})$ and c) $\nu_\mu p \to \mu^- \Sigma_c^{++} (\Sigma_c^{*++})$. The particles inside the ellipse represent the Λ_c^+ decay products.

3.3 Kinematics of the quasi-elastic reaction

Let us assume, for simplicity, the initial nucleon at rest. In this frame, given the transferred 4-momentum squared q^2, the energy of the charmed baryon is

$$E_C = \frac{q^2 + m_C^2 + m_N^2}{2m_N}, \tag{18}$$

where m_C is its mass and m_N is the mass of the struck nucleon. The q^2-distribution, at a fixed neutrino energy, $(1/\sigma)d\sigma/dq^2$ is in general model dependent [12]-[18]. Nevertheless, despite the large disagreement in the theoretical total cross-sections, the predicted q^2-distributions are very similar and lie mostly in the range $0 < q^2 < 2\ GeV^2$. We study the kinematics of the quasi-elastic process at different values of q^2 integrating over the neutrino energy spectrum[2]. As reference values of q^2 we use (0.1, 0.5, 1, 2) GeV^2.

The flight length and the decay kinematics of the Λ_c^+ have been evaluated using the package PYTHIA5.7/JETSET7.4 [24]. The flight length distributions for four different q^2 values are shown in Fig. 2. From this figure we can see that, because of the small γ factor, almost all the Λ_c^+ decay within 500 μm from the production point. This parameter is crucial when we start thinking of a detector able to *see* the topologies shown in Fig. 1.

3.4 Deep inelastic charm processes

Charmed hadrons can be produced in deep inelastic neutrino interactions through the reaction $\nu_\mu N \to \mu^- C X$, where $C = D^0, D^+, D_s^+, \Lambda_c^+$ and X is purely hadronic. Using the CERN-SPS WANF neutrino beam [23], (57±5)% of the charmed particles produced in deep inelastic interactions is neutral. The rest can be split as follows: (19±4)% D^+, (12±4)% D_s^+ and (12±3)% Λ_c^+. For details about the charm production fractions in neutrino interactions we refer

[2] As an example of neutrino beam we considered the CERN-SPS WANF neutrino beam [23], which has an average energy of about of 27 GeV.

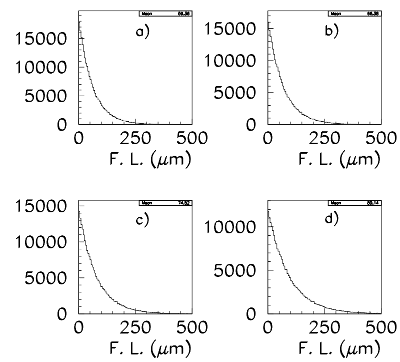

Figure 2: Flight length distribution for different q^2 values: a) $q^2 = 0.1\ GeV^2$, b) $q^2 = 0.5\ GeV^2$, c) $q^2 = 1\ GeV^2$, d) $q^2 = 2\ GeV^2$.

to [25].

Through a Monte Carlo simulation, we also checked that (15.48±0.09)% of the deep inelastic events with a charmed hadron in the final state has a topology similar to those shown in Fig. 1a) and Fig. 1b) and (8.43±0.04)% to the one in Fig. 1c).

3.5 Quasi-elastic versus deep inelastic charm events

A suitable variable to discriminate quasi-elastic from deep inelastic events is the visible hadronic energy, see Fig. 3. According to Eq. (18), a large fraction of the visible energy in quasi-elastic events is expected to lie in the range $(3 \div 5)\,GeV$. It is, indeed, possible to achieve a high rejection power against deep inelastic events keeping high efficiency for quasi-elastic ones. For example, the cut $E_{vis} \leq 5\,GeV$ rejects (97.1±0.1)% of the deep inelastic processes keeping more than 90% of quasi-elastic events.

It is important to have high rejection power against deep inelastic charm production due to its large cross-section [22] ($\sigma(\nu_\mu N \to \mu^- CX)/\sigma(\nu_\mu N \to \mu^- X) \sim 5\%$[3], $\mathcal{R} = 0.6\%$) and to the fact that not only Λ_c^+, but also D^+ and D_s^+ are produced. In fact, D^+ or D_s^+ hadrons, wrongly identified, could bias the determination of the Λ_c^+ branching ratios. The quasi-elastic sample contamination, which comes from deep inelastic events, can be written using Table 1 as

$$\varepsilon_{fake} = \frac{\sigma(\nu_\mu N \to \mu^- CX)}{\sigma(\nu_\mu N \to \mu^- X)} \times \frac{1}{\mathcal{R}} \times f_{fake} \times f_{E<5GeV} \times f_{(D^+ or D_s^+)}\,. \tag{19}$$

[3]This result includes also the production of neutral charmed particles.

$\Delta\mathcal{R}/\mathcal{R}$	$\sigma_{fake}/\varepsilon_{fake}$	ε_{fake}
10%	19%	(0.45±0.09)%
30%	34%	(0.45±0.15)%
50%	53%	(0.45±0.24)%
100%	101%	(0.45±0.45)%
200%	201%	(0.45±0.90)%
500%	500%	(0.45±2.25)%

Table 3: The relative and absolute errors on ε_{fake} are shown as a function of the relative error on $\mathcal{R}$.

The factor $f_{fake}(= (23.9\pm0.1)\%)$ denotes the fraction of deep inelastic events which fakes a quasi-elastic topology, $f_{E<5GeV}(= (2.9\pm0.1)\%)$ is the fraction of the deep inelastic events which survives to the energy cut, and $f_{(D^+ or D_s^+)}(= (8.2\pm0.4)\%)$ is the fraction, among *fake* quasi-elastics, with a charmed meson in the final state. Hence, the contamination is $\varepsilon_{fake} \simeq 0.5\%$. The relative error on ε_{fake} as a function of the relative error on $\mathcal{R}$ is shown in Table 3.

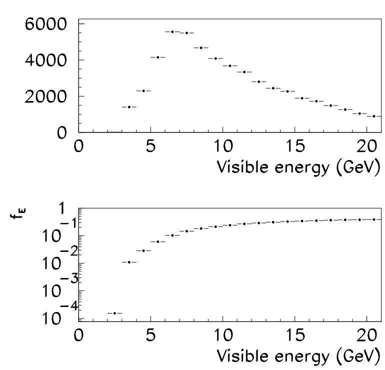

Figure 3: Top: Visible energy distribution of deep inelastic charm events with a vertex topology similar to the one shown in Fig. 1a) and Fig. 1b). Bottom: fraction of deep inelastic charm events faking a quasi-elastic topology as a function of the energy cut.

4 Description of the method

Due to the peculiar topology and kinematics of the quasi-elastic events an almost pure sample of Λ_c^+, with a small contamination of D^+ and D_s^+ produced in deep

inelastic events, can be selected. No model dependent information is used to determine the number of Λ_c^+. The contamination of D^+ and D_s^+ from deep inelastic events can be taken into account assigning it as relative systematic error on the branching ratios. We assumed the relative systematic error to be $\varepsilon_{fake} + 3\sigma_{fake}$. The normalisation to determine the Λ_c^+ absolute branching ratios is simply given by the number of events with a vertex topology consistent with Fig. 1. We want to stress, here, that no model dependent information is used to determine the normalisation. The little knowledge we have about the quasi-elastic charm production cross-section, which is model dependent unless measured, plays a role only in the evaluation of the deep inelastic contamination, namely the systematic error. It is worth noticing that, even if the ratio $\mathcal{R}$ is known with an uncertainty of 500%[4], the relative systematic error on the branching ratios is $\sim 7.2\%$ (see Table 3).

4.1 Measurement accuracy in a *perfect detector*

The *perfect detector* by definition has the following features:

- vertex topology measurement with 100% efficiency resolution for charmed baryon decays;
- infinite energy resolution;
- particle identification capability with infinite resolution.

In Table 4 the expected accuracy on the determination of the Λ_c^+ branching ratios as a function of the relative error on $\mathcal{R}$ is shown. To compute the expected number of events in each decay channel we used the central values (shown in Table 4 together with their errors) given by the Particle Data Group [1]. From this Table we can see that, even assuming very large (unrealistic) systematic error, it is still possible to discriminate among methods $\mathcal{A}$ and $\mathcal{B}$ discussed in Section 2. In Table 5 the achievable accuracy on the absolute BR determination as a function of the collected charged-current statistics is shown.

4.2 Measurement accuracy with statistics of present and future experiments

Among the neutrino experiments which are currently taking data or analysing data, CHORUS [26], which uses nuclear emulsions as a target, has an adequate spatial resolution to fully exploit the topologies shown in Fig. 1. Starting from a sample of about of 500000 charged-current events, it is estimated that ~ 350000 events will be analysed in the emulsions [27]. Assuming a 50% efficiency to detect the Λ_c^+ decay and taking into account that $\mathcal{R} = 0.6\%$, a statistics of $\sim$ 1000 quasi-elastic events can be expected. Due to the good muon identification of the electronic detector and the emulsion capability in identifying electrons,

[4]Nevertheless, this is not the case. We recall that E531 [22], with only 3 events observed, measured $\mathcal{R}$ with an accuracy of 100%.

Channel	PDG BR [1]	ΔBR $(\frac{\Delta\mathcal{R}}{\mathcal{R}} = 10\%)$	ΔBR $(\frac{\Delta\mathcal{R}}{\mathcal{R}} = 100\%)$	ΔBR $(\frac{\Delta\mathcal{R}}{\mathcal{R}} = 500\%)$
$\Lambda_c^+ \to p\bar{K}^0$	(2.5±0.7)%	(±0.2±0.02)%	(±0.2±0.05)%	(±0.2±0.2)%
$\Lambda_c^+ \to pK^-\pi^+$	(5.0±1.3)%	(±0.3±0.04)%	(±0.3±0.09)%	(±0.3±0.4)%
$\Lambda_c^+ \to p\bar{K}^0\eta$	(1.3±0.4)%	(±0.1±0.01)%	(±0.1±0.02)%	(±0.1±0.09)%
$\Lambda_c^+ \to p\bar{K}^0\pi^+\pi^-$	(2.4±1.1)%	(±0.2±0.02)%	(±0.2±0.04)%	(±0.2±0.2)%
$\Lambda_c^+ \to pK^-\pi^+\pi^0$	(4.7±1.3)%	(±0.3±0.04)%	(±0.3±0.08)%	(±0.3±0.3)%
$\Lambda_c^+ \to \Lambda\pi^+\pi^0$	(3.6±1.3)%	(±0.2±0.03)%	(±0.2±0.06)%	(±0.2±0.3)%
$\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-$	(3.3±1.0)%	(±0.2±0.02)%	(±0.2±0.06)%	(±0.2±0.2)%
$\Lambda_c^+ \to \Lambda\pi^+\eta$	(1.7±0.6)%	(±0.2±0.01)%	(±0.2±0.03)%	(±0.2±0.1)%
$\Lambda_c^+ \to \Sigma^+\pi^0$	(1.0±0.3)%	(±0.1±0.01)%	(±0.1±0.02)%	(±0.1±0.07)%
$\Lambda_c^+ \to \Sigma^+\pi^+\pi^-$	(3.4±1.0)%	(±0.2±0.02)%	(±0.2±0.06)%	(±0.2±0.2)%
$\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$	(1.8±0.8)%	(±0.2±0.01)%	(±0.2±0.03)%	(±0.2±0.1)%
$\Lambda_c^+ \to \Sigma^0\pi^+\pi^0$	(1.8±0.8)%	(±0.2±0.01)%	(±0.2±0.03)%	(±0.2±0.1)%
$\Lambda_c^+ \to \Sigma^0\pi^+\pi^+\pi^-$	(1.1±0.4)%	(±0.1±0.01)%	(±0.1±0.02)%	(±0.1±0.08)%
$\Lambda_c^+ \to \Sigma^+\pi^+\pi^-\pi^0$	(2.7±1.0)%	(±0.2±0.02)%	(±0.2±0.05)%	(±0.2±0.2)%
$\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$	(2.0±0.7)%	(±0.2±0.01)%	(±0.2±0.04)%	(±0.2±0.1)%
$\Lambda_c^+ \to \Lambda e^+\nu_e$	(2.1±0.7)%	(±0.2±0.01)%	(±0.2±0.04)%	(±0.2±0.2)%

Table 4: Statistical and systematic accuracy achievable in the determination of the Λ_c^+ absolute branching ratios, assuming a collected statistics of 10^6 ν_μ charged-current events, as a function of the relative error on $\mathcal{R}$. The central values are taken from ref. [1].

Channel	$N_\mu = 10^6$	$N_\mu = 10^5$	$N_\mu = 10^4$
$\Lambda_c^+ \to p\bar{K}^0$	(±0.2±0.05)%	(±0.6±0.05)%	(±1.8±0.05)%
$\Lambda_c^+ \to pK^-\pi^+$	(±0.3±0.09)%	(±0.9±0.09)%	(±2.8±0.09)%
$\Lambda_c^+ \to p\bar{K}^0\eta$	(±0.1±0.02)%	(±0.5±0.02)%	(±1.7±0.02)%
$\Lambda_c^+ \to p\bar{K}^0\pi^+\pi^-$	(±0.2±0.04)%	(±0.6±0.04)%	(±1.0±0.04)%
$\Lambda_c^+ \to pK^-\pi^+\pi^0$	(±0.3±0.08)%	(±0.9±0.08)%	(±2.8±0.08)%
$\Lambda_c^+ \to \Lambda\pi^+\pi^0$	(±0.2±0.06)%	(±0.8±0.06)%	(±2.3±0.06)%
$\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-$	(±0.2±0.06)%	(±0.7±0.06)%	(±2.3±0.06)%
$\Lambda_c^+ \to \Lambda\pi^+\eta$	(±0.2±0.03)%	(±0.5±0.03)%	(±1.7±0.03)%
$\Lambda_c^+ \to \Sigma^+\pi^0$	(±0.1±0.02)%	(±0.4±0.02)%	(±1.0±0.02)%
$\Lambda_c^+ \to \Sigma^+\pi^+\pi^-$	(±0.2±0.06)%	(±0.7±0.06)%	(±2.3±0.06)%
$\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$	(±0.2±0.03)%	(±0.5±0.03)%	(±1.7±0.03)%
$\Lambda_c^+ \to \Sigma^0\pi^+\pi^0$	(±0.2±0.03)%	(±0.5±0.03)%	(±1.7±0.03)%
$\Lambda_c^+ \to \Sigma^0\pi^+\pi^+\pi^-$	(±0.1±0.02)%	(±0.4±0.02)%	(±1.0±0.02)%
$\Lambda_c^+ \to \Sigma^+\pi^+\pi^-\pi^0$	(±0.2±0.05)%	(±0.7±0.05)%	(±2.2±0.05)%
$\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$	(±0.2±0.04)%	(±0.6±0.04)%	(±1.8±0.04)%
$\Lambda_c^+ \to \Lambda e^+\nu_e$	(±0.2±0.04)%	(±0.6±0.04)%	(±1.8±0.04)%

Table 5: Accuracy achievable (ΔBR), assuming a 100% error on $\mathcal{R}$, as a function of the collected charged-current statistics.

CHORUS is well suited to study Λ_c^+ semi-leptonic decays. Assuming 100% error on $\mathcal{R}$ and the PDG central value [1], the following accuracy could be achieved:

$$\Delta BR(\Lambda_c^+ \to \Lambda\mu^+\nu_\mu) = (\pm 0.44\,|_{stat} \pm 0.01\,|_{sys})\% \tag{20}$$

$$\Delta BR(\Lambda_c^+ \to \Lambda e^+\nu_e) = (\pm 0.45\,|_{stat} \pm 0.01\,|_{sys})\% \tag{21}$$

A measurement with higher sensitivity could be performed exposing a dedicated detector, whose feasibility study has not yet been worked out, at the future neutrino beams from muon storage rings [28]. Such beams could provide $\mathcal{O}(10^6)$ $\nu_\mu - CC$ *events/year* in a 10 *kg* fiducial mass detector, 1 *km* away from the neutrino source, allowing for a strong reduction of the statistical uncertainty on the Λ_c branching ratios, see Table 5.

Conclusions

We have presented a new method for a direct evaluation of the Λ_c^+ branching ratios. We have also stressed that this has very interesting consequences for our understanding of baryon production in charm decays. Even just a good determination of the Λ_c^+ semi-leptonic exclusive decay widths would be sufficient: indeed from Eq.(4) we would determine $BR(\Lambda_c^+ \to pK^-\pi^+)$, very important phenomenologically as pointed out particularly in Section 2. We have also shown that, already with existing data, it should be possible to perform a direct measurement of Λ_c^+ exclusive decay widths, which is lacking to date.

References

[1] Particle Data Group, Euro. Phys. J. 1 (1998) 1.

[2] I. Dunietz, Phys. Rev. D 58 (1998) 094010.

[3] H. Albrecht et al., ARGUS Collaboration, Phys. Lett. B 207 (1988) 109.

[4] G. Crawford et al., CLEO Collaboration, Phys. Rev. D 45 (1992) 752.

[5] H. Albrecht et al., ARGUS Collaboration, Z. Phys. C 56 (1992) 1.

[6] H. Albrecht et al., ARGUS Collaboration, Phys. Rept. 276 (1996) 223.

[7] P. Avery et al., CLEO Collaboration, Phys. Rev. D 43 (1991) 3599.

[8] H. Albrecht et al., ARGUS Collaboration, Phys. Lett. B 269 (1991) 134.

[9] T. Bergfeld et al., CLEO Collaboration, Phys. Lett. B 323 (1994) 219.

[10] A. Bean et al., CLEO Collaboration, Phys. Lett. B 317 (1993) 647.

[11] J. Chay, H. Georgi, B. Grinstein, Phys. Lett. B 247 (1990) 399; I.I. Bigi, N.G. Uraltsev, A.I. Vainshtein, Phys. Lett. B 293 (1992) 430, Erratum Phys. Lett. B 297 (1993) 477; A. Manohar and M.B. Wise, Phys. Rev. D 49(1994) 1310; I.I. Bigi, hep-ph/9508408;

[12] J. Finjord and F. Ravndal, Phys. Lett. B 58 (1975) 61.

[13] R.E. Shrock and B.W. Lee, Phys. Rev. D 13 (1976) 2539.

[14] C. Avilez et al., Phys. Lett. B 66 (1977) 149.
[15] C. Avilez and T. Kobayashi, Phys. Rev. D 19 (1979) 3448.
[16] C. Avilez et al., Phys. Rev. D 17 (1978) 709.
[17] A. Amer et al., Phys. Lett. B 81 (1979) 48.
[18] S.G. Kovalenko, Sov. J. Nucl. Phys. 52 (1990) 934.
[19] E.D. Bloom and F.G. Gilman, Phys. Rev. D 4 (1971) 2901.
[20] A. De Rújula et al., Ann. Phys. 103 (1977) 315.
[21] A. De Rújula et al., Phys. Rev. D 15 (1977) 2415.
[22] N. Ushida et al., E531 Collaboration, Phys. Lett. B 206 (1988) 375.
[23] G. Acquistapace et al., CERN Preprint, CERN-ECP/95-14, 1995.
[24] T. Sjöstrand, Comp. Phys. Comm. 82 (1994) 74.
[25] T. Bolton, hep-ex/9708014.
[26] E. Eskut et al., Nucl. Instr. Meth. A 401 (1998) 7.
[27] E. Eskut et al., Phys. Lett. B 424 (1998) 202; E. Eskut et al., Phys. Lett. B 434 (1998) 205.
[28] S. Geer, Phys. Rev. D 57 (1998) 1.